

SURFACE-BRIGHTNESS EVOLUTION OF CLUSTER GALAXIES

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Surface brightness evolution has been detected in elliptical galaxies (consistent with passive evolution models of old stellar populations) and in disk galaxies (presumably due to enhanced star-formation rates). The rates of evolution in clusters and the field are not measurably different. In addition to this similarity, the high-redshift populations in both environments exhibit a “blue-excess” population, increased rates of star formation, and high frequency of peculiar structure. Thus, there are several parallels between evolving cluster and field galaxies and the high-redshift cluster environment will be understood only by comparison with the field population *at the same epoch*.

1 Introduction

In the course of programs to understand the evolution of galaxies by focusing on morphological properties, two-dimensional surface photometry has been done for samples of field galaxies^{22,23} and cluster galaxies^{23,24} using *HST*, ground-based imaging, and *HST* archival data. The cluster and field galaxy populations were much more similar at $z \sim 0.5$ than they are at the present time.

2 Recent results on high-redshift clusters

2.1 Elliptical galaxies

Ellipticals are present in clusters at high redshift⁸ and their colours are consistent with passive evolution models.^{10,1,20,18} The small dispersion in the colour-luminosity relation at $z \sim 0.5$ ¹¹ suggests they formed at substantially earlier epochs. Bender, Ziegler & Bruzua³ find evidence from the Mgb- σ and Faber-Jackson relations for passive evolution in the *B*-band of 0.5 ± 0.1 in a cluster at $z = 0.37$, a result consistent with fundamental plane work at $z = 0.39$ ²⁷.

Imaging has been used to search for evolution in the size-luminosity relation—one projection of the fundamental plane—of elliptical galaxies. Schade et al.^{25,26} analysed ground-based and *HST* imaging and find an increase with redshift in surface brightness or luminosity (at a given size) of $\Delta M_B \sim -z$, consistent with both the spectroscopic studies cited above and with other imaging work^{19,2}. Thus, the luminosity evolution expected from passive evolution models of elliptical galaxies has been detected by several groups.

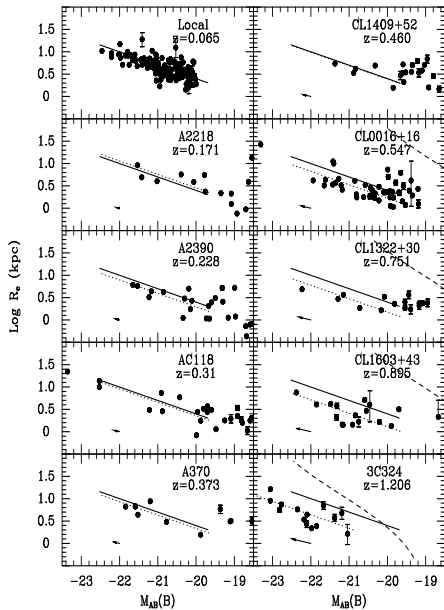


Figure 1: The evolving size-luminosity relation for elliptical galaxies derived from *HST* archival imaging of 9 clusters with $0 < z < 1.2$ ²⁶. Galaxies of a given size are more luminous by ~ 1 mag at $z = 1$. Solid lines show the local relation and dotted lines indicate the evolved relation measured in each cluster. (Long-dashed lines indicate the surface-brightness selection.)

2.2 Blue cluster galaxies

The blue fraction of the cluster galaxy population increases from a few percent locally to 25% at $z \sim 0.5$ ⁴ and, by $z \sim 0.9$, perhaps 80% of cluster galaxies were blue.²⁰ This blue population shows spectroscopic signs of enhanced levels of star-formation⁶ and is made up largely of disk-like galaxies with a high frequency of peculiar/irregular structure.^{21,16,9,7} Surface photometry of galaxies (with redshifts) from the Canadian Network for Observational Cosmology (CNOC) cluster survey⁵ shows that galactic disks in 3 clusters have surface brightness higher than the Freeman¹² value by ~ 1 mag at $z = 0.5$ ²⁴. Furthermore, this disk brightening is consistent with observations of field galaxies.^{23,22,24}

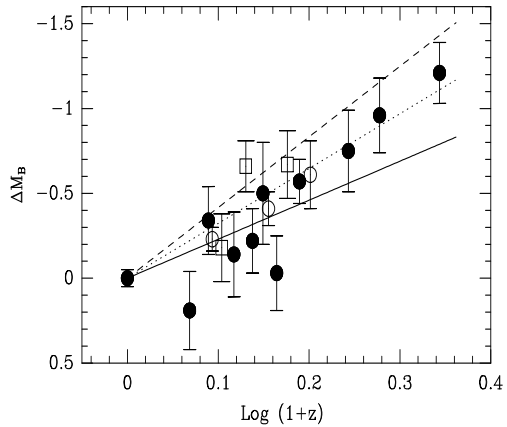


Figure 2: ΔM_B is the shift in luminosity at a given size as measured, e.g., from figure 1. Solid symbols are for cluster elliptical galaxies using *HST* imaging (but no membership information) and open symbols are from ground-based imaging of CNOC fields²⁵ where all of the galaxies have redshift information (open circles=cluster E's, open squares=field E's.)

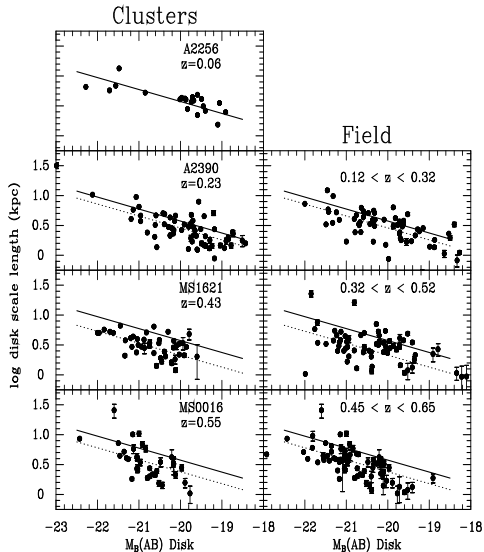


Figure 3: The evolving size-luminosity relation for galactic disks in clusters and the field²⁴. Solid lines show the Freeman¹² law and dotted lines indicate the mean evolved relation.

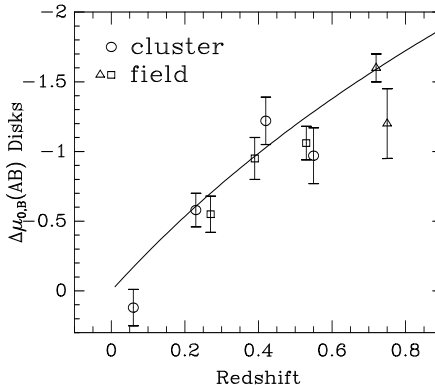


Figure 4: ΔM_B is the shift in surface brightness relative to the Freeman law measured, e.g. from plots like Figure 3. Open circles are CNOC cluster galaxies and squares are CNOC field galaxies. Triangles are field galaxies from Schade et al.^{22,24}. The line is the evolution of the luminosity density $((1+z)^{2.7})$ in the B -band from Lilly et al.¹⁵.

3 Parallels of cluster and field population at high- z

Cluster and field populations are dominated at high redshift by a “blue-excess” population that is mysteriously “absent” from the local population^{14,9}. Both populations show a high (and similar) frequency of peculiar/irregular structure,^{13,7} and both populations show elevated rates of star formation relative to local populations^{17,6}. It has been argued here that field and cluster populations also show evolution in surface brightness (both disks and ellipticals) and that the rates of evolution are not measurably different (although the cluster population we have studied consists largely of galaxies far from the dense cluster core).

These similarities suggest that much of the physics of galaxy evolution is common to cluster and field populations and that the development of the high- z cluster population, largely through infall of field galaxies, needs to be understood in the context of the field population *at that redshift*, whose state differs markedly from the population we see in the present-day universe.

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